others. And it is these empirical laws which are embodied and expressed in a natural classification.

II. DISTRIBUTION.

Living beings occupy certain portions of the surface of the earth, inhabiting either the dry land or the fresh or salt waters, or being competent to maintain their existence in either. In any given locality, it is found that those different media are inhabited by different kinds of living beings; and that the same medium, at different heights in the air and at different depths in the water, has different living inhabitants.

Moreover, the living populations of localities which differ considerably in latitude, and hence in climate, always present considerable differences. But the converse proposition is not true; that is to say, localities which differ in longitude, even if they resemble one another in climate, often have very dissimilar *faunæ* and *floræ*.

It has been discovered by careful comparison of local faunæ and floræ that certain areas of the earth's surface are inhabited by groups of animals and plants which are not found elsewhere, and which thus characterize each of these areas. Such areas are termed *Provinces of Distribution*. There is no parity between these provinces in extent, nor in the physical configuration of their boundaries; and, in reference to existing conditions, nothing can appear to be more arbitrary and capricious than the distribution of living beings.

Geological distribution.

The study of distribution is not confined to the present order of nature; but, by the help of geology, the naturalist is enabled to obtain clear, though too fragmentary, evidence of the characters of the faunæ and floræ of antecedent epochs. The remains of organisms which are contained in the stratified rocks prove that, in any given part of the earth's surface, the living population of earlier epochs was different from that which now exists in the locality; and that, on the whole, the difference becomes greater the farther we go back in time. The organic remains which are found in the later Cainozoic deposits of any district are always closely allied to those now found in the province of distribution in which that locality is included; while in the older Cainozoic, the Mesozoic, and the Palæozoic strata, the fossils may be similar to creatures at present living in some other province, or may be altogether unlike any which now exist.

Continuity of succession of forms of life in time.

In any given locality, the succession of living forms may appear to be interrupted by numerous breaks—the associated species in each fossiliferous bed being quite distinct from those above and those below them. But the tendency of all palæontological investigation is to show that these breaks are only apparent, and arise from the incompleteness of the series of remains which happens to have been preserved in any given locality. As the area over which accurate geological investigations have been carried on extends, and as the fossiliferous rocks found in one locality fill up the gaps left in another, so do the abrupt demarcations between the faunæ and floræ of successive epochs disappear—a certain proportion of the genera and species of every period, great or small, being found to be continued for a longer or shorter time into the next succeeding period. It is evident, in fact, that the changes in the living population of the globe which have taken place during its history, have been effected, not by the sudden replacement of one set of living beings by another, but by a process of slow and gradual introduction of new species, accompanied by the extinction of the older forms.

It is a remarkable circumstance, that in all parts of the globe in which fossiliferous rocks have yet been examined, the successive terms of the series of living forms which have thus succeeded one another are analogous. The life of the Mesozoic epoch is everywhere characterized by the abundance of some groups of species of which no trace is to be found in either earlier or later formations; and the like is true of the Palæozoic epoch. Hence it follows, not only that there has been a succession of species, but that the general nature of that succession has been the same all over the globe; and it is on this ground that fossils are so important to the geologist as marks of the relative age of rocks.

The determination of the morphological relations of the species which have thus succeeded one another is a problem of profound importance and difficulty, the solution of which, however, is already clearly indicated. For, in several cases, it is possible to show that, in the same geographical area, a form A, which existed during a certain geological epoch, has been replaced by another form B, at a later period; and that this form B has been replaced, still later, by a third form C. When these forms, A, B, and C, are compared together they are found to be organized upon the same plan, and to be very similar even in most of the details of their structure; but B differs from A by a slight modification of some of its parts, which modification is carried to a still greater extent in C.

Progressive specialization of forms of life in time.

In other words, A, B, and C differ from one another in the same fashion as the earlier and later stages of the embryo of the same animals differ; and in successive epochs we have the group presenting that progressive specialization which characterises the development of the individual. Clear evidence that this progressive specialization of structure has actually occurred has as yet been obtained in only a few cases (*e.g.*, *Equidæ*, *Crocodilia*), and these are confined to the highest and most complicated forms of life; while it is demonstrable that, even as reckoned by geological time, the process must have been exceedingly slow.

Among the lower and less complicated forms the evidence of progressive modifications, furnished by comparison of the oldest with the latest forms, is slight, or absent; and some of these have certainly persisted, with very little change, from extremely ancient times to the present day. It is as important to recognize the fact that certain forms of life have thus persisted, as it is to admit that others have undergone progressive modification.

Geographical distribution of ancient faunæ and floræ.

It has been said that the successive terms in the series of living forms are analogous in all parts of the globe. But the species which constitute the corresponding or *homotaxic* terms in the series, in different localities, are not identical. And, though the imperfection of our knowledge at present precludes positive assertion, there is every reason to believe that geographical provinces have existed throughout the period during which organic remains furnish us with evidence of the existence of life. The wide distribution of certain Palæozoic forms does not militate against this view; for the recent investigations into the nature of the deep-sea fauna have shown that numerous *Crustacea*, *Echinodermata*, and other invertebrate animals, have as wide a distribution now as their analogues possessed in the Silurian epoch.

III. PHYSIOLOGY.

Thus far living beings have been regarded merely as definite forms of matter, and Biology has presented no considerations of a different order from those which meet the student of Mineralogy. But living things are not only natural bodies, having a definite form and mode of structure, growth, and development. They are machines in action; and, under this aspect, the phenomena which they present have no parallel in the mineral world.

The actions of living matter are termed its *functions*; and these functions, varied as they are, may be reduced to

three categories. They are either—(1), functions which affect the material composition of the body, and determine its mass, which is the balance of the processes of waste on the one hand and those of assimilation on the other. Or (2), they are functions which subserve the process of reproduction, which is essentially the detachment of a part endowed with the power of developing into an independent whole. Or (3), they are functions in virtue of which one part of the body is able to exert a direct influence on another, and the body, by its parts or as a whole, becomes a source of molar motion. The first may be termed *sustentative*, the second *generative*, and the third *correlative* functions.

Of these three classes of functions the first two only can be said to be invariably present in living beings, all of which are nourished, grow, and multiply. But there are some forms of life, such as many *Fungi*, which are not known to possess any powers of changing their form; in which the protoplasm exhibits no movements, and reacts upon no stimulus; and in which any influence which the different parts of the body exert upon one another must be transmitted indirectly from molecule to molecule of the common mass. In most of the lowest plants, however, and in all animals yet known, the body either constantly or temporarily changes its form, either with or without the application of a special stimulus, and thereby modifies the relations of its parts to one another, and of the whole to surrounding bodies; while, in all the higher animals, the different parts of the body are able to affect, and be affected by, one another, by means of a special tissue, termed *nerve*. Molar motion is effected on a large scale by means of another special tissue, *muscle*; and the organism is brought into relation with surrounding bodies by means of a third kind of special tissue—that of the *sensory organs*—by means of which the forces exerted by surrounding bodies are transmuted into affections of nerve.

In the lowest forms of life, the functions which have been enumerated are seen in their simplest forms, and they are exerted indifferently, or nearly so, by all parts of the protoplasmic body; and the like is true of the functions of the body of even the highest organisms, so long as they are in the condition of the nucleated cell, which constitutes the starting point of their development. But the first process in that development is the division of the germ into a number of morphological units or blastomeres, which, eventually, give rise to cells; and as each of these possesses the same physiological functions as the germ itself, it follows that each morphological unit is also a physiological unit, and the multicellular mass is strictly a compound organism, made up of a multitude of physiologically independent cells. The physiological activities manifested by the complex whole represent the sum, or rather the resultant, of the separate and independent physiological activities resident in each of the simpler constituents of that whole.

The morphological changes which the cells undergo in the course of the further development of the organism do not affect their individuality; and, notwithstanding the modification and confluence of its constituent cells, the adult organism, however complex, is still an aggregate of morphological units. Nor is it less an aggregate of physiological units, each of which retains its fundamental independence, though that independence becomes restricted in various ways.

Each cell, or that element of a tissue which proceeds from the modification of a cell, must needs retain its sustentative functions so long as it grows or maintains a condition of equilibrium; but the most completely metamorphosed cells show no trace of the generative function, and many exhibit no correlative functions. On the other hand, those cells of the adult organism which are the unmetamorphosed derivatives of the germ, exhibit all the primary functions, not only nourishing themselves and growing, but multiplying, and frequently showing more or less marked movements.

Organs are parts of the body which perform particular functions. In strictness, perhaps, it is not quite right to speak of organs of sustentation or generation, each of these functions being necessarily performed by the morphological unit which is nourished or reproduced. What are called the organs of these functions are the apparatuses by which certain operations, subsidiary to sustentation and generation, are carried on.

Thus, in the case of the sustentative functions, all those organs may be said to contribute to this function which are concerned in bringing nutriment within reach of the ultimate cells, or in removing waste matter from them; while in the case of the generative function, all those organs contribute to the function which produce the cells from which germs are given off; or help in the evacuation, or fertilization, or development of these germs.

On the other hand, the correlative functions, so long as they are exerted by a simple undifferentiated morphological unit or cell, are of the simplest character, consisting of those modifications of position which can be effected by mere changes in the form or arrangement of the parts of the protoplasm, or of those prolongations of the protoplasm which are called pseudopodia or cilia. But, in the higher animals and plants, the movements of the organism and of its parts are brought about by the change of the form of certain tissues, the property of which is to shorten in one direction when exposed to certain stimuli. Such tissues are termed *contractile*; and, in their most fully developed condition, *muscular*. The stimulus by which this contraction is naturally brought about is a molecular change, either in the substance of the contractile tissue itself, or in some other part of the body; in which latter case, the motion which is set up in that part of the body must be propagated to the contractile tissue through the intermediate substance of the body. In plants there seems to be no question that parts which retain a hardly modified cellular structure may serve as channels for the transmission of this molecular motion; whether the same is true of animals is not certain. But, in all the more complex animals, a peculiar fibrous tissue—*nerve*—serves as the agent by which contractile tissue is affected by changes occurring elsewhere, and by which contractions thus initiated are co-ordinated and brought into harmonious combination. While the sustentative functions in the higher forms of life are still, as in the lower, fundamentally dependent upon the powers inherent in all the physiological units which make up the body, the correlative functions are, in the former, deputed to two sets of specially modified units, which constitute the muscular and the nervous tissues.

When the different forms of life are compared together as physiological machines, they are found to differ as machines of human construction do. In the lower forms, the mechanism, though perfectly well adapted to do the work for which it is required, is rough, simple, and weak; while, in the higher, it is finished, complicated, and powerful. Considered as machines, there is the same sort of difference between a polype and a horse as there is between a distaff and a spinning-jenny. In the progress from the lower to the higher organism, there is a gradual differentiation of organs and of functions. Each function is separated into many parts, which are severally entrusted to distinct organs. To use the striking phrase of Milne-Edwards, in passing from low to high organisms, there is a division of physiological labour. And exactly the same process is observable in the development of any of the higher organisms; so that, physiologically, as well as morphologically, development is a progress from the general to the special.

Thus far, the physiological activities of living matter have been considered in themselves, and without reference to anything that may affect them in the world outside the living body. But living matter acts on, and is powerfully affected by, the bodies which surround it; and the study of the influence of the "conditions of existence" thus determined constitutes a most important part of Physiology.

The sustentative functions, for example, can only be exerted under certain conditions of temperature, pressure, and light, in certain media, and with supplies of particular kinds of nutritive matter; the sufficiency of which supplies, again, is greatly influenced by the competition of other organisms, which, striving to satisfy the same needs, give rise to the passive "struggle for existence." The exercise of the correlative functions is influenced by similar conditions, and by the direct conflict with other organisms, which constitutes the active struggle for existence. And, finally, the generative functions are subject to extensive modifications, dependent partly upon what are commonly called external conditions, and partly upon wholly unknown agencies.

Reproduction by fission and gemmation: agamogenesis.

In the lowest forms of life, the only mode of generation at present known is the division of the body into two or more parts, each of which then grows to the size and assumes the form of its parent, and repeats the process of multiplication. This method of multiplication by *fission* is properly called generation, because the parts which are separated are severally competent to give rise to individual organisms of the same nature as that from which they arose.

In many of the lowest organisms the process is modified so far that, instead of the parent dividing into two equal parts, only a small portion of its substance is detached, as a bud which develops into the likeness of its parent. This is generation by *gemmation*. Generation by fission and by gemmation are not confined to the simplest forms of life, however. On the contrary, both modes of multiplication are common not only among plants, but among animals of considerable complexity.

The multiplication of flowering plants by bulbs, that of annelids by fission, and that of polypes by budding, are well-known examples of these modes of reproduction. In all these cases, the bud or the segment consists of a multitude of more or less metamorphosed cells. But, in other instances, a single cell detached from a mass of such undifferentiated cells contained in the parental organism is the foundation of the new organism, and it is hard to say whether such a detached cell may be more fitly called a bud or a segment—whether the process is more akin to fission or to gemmation.

In all these cases the development of the new being from the detached germ takes place without the influence of other living matter. Common as the process is in plants and in the lower animals, it becomes rare among the higher animals. In these, the reproduction of the whole organism from a part, in the way indicated above, ceases. At most, we find that the cells at the end of an amputated portion of the organism are capable of reproducing the lost part; and, in the very highest animals, even this power vanishes in the adult; and, in most parts of the body, though the undifferentiated cells are capable of multiplication, their progeny grow, not into whole organisms like that of which they form a part, but into elements of the tissues.

Throughout almost the whole series of living beings, however, we find concurrently with the process of *agamogenesis*, or asexual generation, another method of generation in which the development of the germ into an organism resembling the parent depends on an influence exerted by living matter different from the germ. This is *gamogenesis*, or sexual generation. Looking at the facts broadly, and without reference to many exceptions in detail, it may be said that there is an inverse relation between agamogenetic and gamogenetic reproduction. In the lowest organisms gamogenesis has not yet been observed, while in the highest agamogenesis is absent. In many of the lower forms of life agamogenesis is the common and predominant mode of reproduction, while gamogenesis is exceptional; on the contrary, in many of the higher, while gamogenesis is the rule, agamogenesis takes place exceptionally. In its simplest condition, which is termed "*conjugation*," sexual generation consists in the coalescence of two similar masses of protoplasmic matter, derived from different parts of the same organism, or from two organisms of the same species, and the single mass which results from the fusion develops into a new organism.

In the majority of cases, however, there is a marked morphological difference between the two factors in the process, and then one is called the male, and the other the female element. The female element is relatively large, and undergoes but little change of form. In all the higher plants and animals it is a nucleated cell, to which a greater or less amount of nutritive material, constituting the food-yelk, may be added.

The male element, on the other hand, is relatively small. It may be conveyed to the female element by an outgrowth of the wall of its cell, which is short in many *Algæ* and *Fungi*, but becomes an immensely elongated tubular filament, in the case of the pollen cell of flowering plants. But, more commonly, the protoplasm of the male cells becomes converted into rods or filaments, which usually are in active vibratile movement, and sometimes are propelled by numerous cilia. Occasionally, however, as in many *Nematoidea* and *Arthropoda*, they are devoid of mobility.

The manner in which the contents of the pollen tube affect the embryo cell in flowering plants is unknown, as no perforations through which the contents of the pollen tube may pass, so as actually to mix with the substance of the embryo cell, have been discovered; and there is the same difficulty with respect to the conjugative processes of some of the *Cryptogamia*. But in the great majority of plants, and in all animals, there can be no doubt that the substance of the male element actually mixes with that of the female, so that in all these cases the sexual process remains one of conjugation; and impregnation is the physical admixture of protoplasmic matter derived from two sources, which may be either different parts of the same organism, or different organisms.

Immediate consequences of fecundation.

The effect of impregnation appears in all cases to be that the impregnated protoplasm tends to divide into portions (*blastomeres*), which may remain united as a single cell-aggregate, or some or all of which may become separate organisms. A larger or shorter period of rest, in many cases, intervenes between the act of impregnation and the commencement of the process of division.

As a general rule, the female cell which directly receives the influence of the male is that which undergoes division and eventual development into independent germs; but there are some plants, such as the *Florideæ*, in which this is not the case. In these the protoplasmic body of the trichogyne, which unites with the molecular spermatozoids, does not undergo division itself, but transmits some influence to adjacent cells, in virtue of which they become subdivided into independent germs or spores.

There is still much obscurity respecting the reproductive processes of the *Infusoria*; but, in the *Vorticellidæ*, it would appear that conjugation merely determines a condition of the whole organism, which gives rise to the division of the endoplast or so-called nucleus, by which germs are thrown off; and if this be the case, the process would have some analogy to what takes place in the *Florideæ*.

On the other hand, the process of conjugation by which two distinct *Diporpæ* combine into that extraordinary double organism, the *Diplozoon paradoxum*, does not directly give rise to germs, but determines the development of the sexual organs in each of the conjugated individuals; and the same process takes place in a large number of the *Infusoria*, if what are supposed to be male sexual elements in them are really such.

The process of impregnation in the *Florideæ* is remarkably interesting, from its bearing upon the changes which fecundation is known to produce upon parts of the parental organism other than the ovum, even in the highest animals and plants.

The nature of the influence exerted by the male element upon the female is wholly unknown. No morphological distinction can be drawn between those cells which are capable of reproducing the whole organism without impregnation, and those which need it, as is obvious from what happens in insects, where eggs which ordinarily require impregnation, exceptionally, as in many moths, or regularly, as in the case of the drones among bees, develop without impregnation. Even in the higher animals, such as the fowl, the earlier stages of division of the germ may take place without impregnation.

In fact, generation may be regarded as a particular case of cell multiplication, and impregnation simply as one of the many conditions which may determine or affect that process. In the lowest organisms, the simple protoplasmic mass divides, and each part retains all the physiological properties of the whole, and consequently constitutes a germ whence the whole body can be reproduced. In more advanced organisms, each of the multitude of cells into which the embryo cell is converted at first, probably retains all, or nearly all, the physiological capabilities of the whole, and is capable of serving as a reproductive germ; but as division goes on, and many of the cells which result from division acquire special morphological and physiological properties, it seems not improbable that they, in proportion, lose their more general characters. In proportion, for example, as the tendency of a given cell to become a muscle cell or a cartilage cell is more marked and definite, it is readily conceivable that its primitive capacity to reproduce the whole organism should be reduced, though it might not be altogether abolished. If this view is well based, the power of reproducing the whole organism would be limited to those cells which had acquired no special tendencies, and consequently had retained all the powers of the primitive cell in which the organism commenced its existence. The more extensively diffused such cells were, the more generally might multiplication by budding or fission take place; the more localized, the more limited would be the parts of the organism in which such a process would take place. And even where such cells occurred, their development or non-development might be connected with conditions of nutrition. It depends on the nutriment supplied to the female larva of a bee whether it shall become a neuter or a sexually perfect female; and the sexual perfection of a large proportion of the internal parasites is similarly dependent upon their food, and perhaps on other conditions, such as the temperature of the medium in which they live. Thus the gradual disappearance of agamogenesis in the higher animals would be related with that increasing specialization of function which is their essential characteristic; and when it ceases to occur altogether, it may be supposed that no cells are left which retain unmodified the powers of the primitive embryo cell. The organism is like a society in which every one is so engrossed by his special business that he has neither time nor inclination to marry.

Even the female elements in the highest organisms, little as they differ to all appearance from undifferentiated cells, and though they are directly derived from epithelial cells which have undergone very little modification from the condition of blastomeres, are incapable of full development unless they are subjected to the influence of the male element, which may, as Caspar Wolff suggested, be compared to a kind of nutriment. But it is a living nutriment, in some respects comparable to that which would be supplied to an animal kept alive by transfusion, and its molecules transfer to the impregnated embryo cell all the special characters of the organism to which it belonged.

The tendency of the germ to reproduce the characters of its immediate parents, combined, in the case of sexual generation, with the tendency to reproduce the characters of the male, is the source of the singular phenomena of hereditary transmission. No structural modification is so slight, and no functional peculiarity is so insignificant in either parent that it may not make its appearance in the offspring. But the transmission of parental peculiarities depends greatly upon the manner in which they have been acquired. Such as have arisen naturally, and have been hereditary through many antecedent generations, tend to appear in the progeny with great force; while artificial modifications, such, for example, as result from mutilation, are rarely, if ever, transmitted. Circumcision through innumerable ancestral generations does not appear to have reduced that rite to a mere formality, as it should have done, if the abbreviated prepuce had become hereditary in the descendants of Abraham; while modern lambs are born with long tails, notwithstanding the long-continued practice of cutting those of every generation short. And it remains to be seen whether the supposed hereditary transmission of the habit of retrieving among dogs is really what it seems at first sight to be; on the other side, Brown-Sèquard's case of the transmission of artificially induced epilepsy in guinea-pigs is undoubtedly very weighty.

Variation.

Although the germ always tends to reproduce, directly or indirectly, the organism from which it is derived, the result of its development differs somewhat from the parent. Usually the amount of variation is insignificant; but it may be considerable, as in the so-called "sports;" and such variations, whether useful or useless, may be transmitted with great tenacity to the offspring of the subjects of them.

In many plants and animals which multiply both asexually and sexually, there is no definite relation between the agamogenetic and the gamogenetic phenomena. The organism may multiply asexually before, or after, or concurrently with, the occurrence of sexual generation.

But in a great many of the lower organisms, both animal and vegetable, the organism (A) which results from the impregnated germ produces offspring only agamogenetically. It thus gives rise to a series of independent organisms (B, B, B, . . .), which are more or less different from A, and which sooner or later acquire generative organs. From their impregnated germs A is reproduced. The process thus described is what has been termed the "alternation of generations" under its simplest form,—for example, as it is exhibited by the *Salpæ*. In more complicated cases, the independent organisms which correspond with B may give rise agamogenetically to others (B_1), and these to others (B_2), and so on (*e.g.*, *Aphis*). But, however long the series, a final term appears which develops sexual organs, and reproduces A. The "alternation of generations" is, therefore, in strictness, an alternation of asexual with sexual generation, in which the products of the one process differ from those of the other.

The *Hydrozoa* offer a complete series of gradations between those cases in which the term B is represented by a free, self-nourishing organism (*e.g., Cyanæa*), through those in which it is free but unable to feed itself (*Calycophoridæ*), to those in which the sexual elements are developed in bodies which resemble free zoöids, but are never detached, and are mere generative organs of the body on which they are developed (*Cordylophora*).

In the last case, the "individual" is the total product of the development of the impregnated embryo, all the parts of which remain in material continuity with one another The multiplication of mouths and stomachs in a *Cordylophora* no more makes it an aggregation of different individuals than the multiplication of segments and legs in a centipede converts that Arthropod into a compound animal. The *Cordylophora* is a differentiation of a whole into many parts, and the use of any terminology which implies that it results from the coalescence of many parts into a whole is to be deprecated.

In *Cordylophora* the generative organs are incapable of maintaining a separate existence; but in nearly allied *Hydrozoa* the unquestionable homologues of these organs become free zoöids, in many cases capable of feeding and growing, and developing the sexual elements only after they have undergone considerable changes of form. Morphologically, the swarm of *Medusæ* thus set free from a Hydrozoon are as much organs of the latter, as the multitudinous pinnules of a *Comatula*, with their genital glands, are organs of the Echinoderm. Morphologically, therefore, the equivalent of the individual *Comatula* is the Hydrozoic stock + all the *Medusæ* which proceed from it.

No doubt it sounds paradoxical to speak of a million of *Aphides*, for example, as parts of one morphological individual; but beyond the momentary shock of the paradox no harm is done. On the other hand, if the asexual *Aphides* are held to be individuals, it follows, as a logical consequence, not only that all the polypes on a *Cordylophora* tree are "feeding individuals," and all the genital sacs "generative individuals," while the stem must be a "stump individual," but that the eyes and legs of a lobster are "ocular" and "locomotive individuals." And this conception is not only somewhat more paradoxical than the other, but suggests a conception of the origin of the complexity of animal structure which is wholly inconsistent with fact.

IV. Ætiology.

Morphology, Distribution, and Physiology investigate and determine the facts of Biology. Ætiology has for its object the ascertainment of the causes of these facts, and the explanation of biological phenomena, by showing that they constitute particular cases of general physical laws. It is hardly needful to say that ætiology, as thus conceived, is in its infancy, and that the seething controversies, to which the attempt to found this branch of science made in the *Origin of Species* has given rise, cannot be dealt with in the limits of this article. At most, the general nature of the problems to be evolved, and the course of inquiry needful for their solution, may be indicated.

In any investigation into the causes of the phenomena of life, the first question which arises is, whether we have any knowledge, and if so, what knowledge, of the origin of living matter?

In the case of all conspicuous and easily-studied organisms, it has been obvious, since the study of nature began, that living beings arise by generation from living beings of a like kind; but before the latter part of the 17th century, learned and unlearned alike shared the conviction that this rule was not of universal application, and that multitudes of the smaller and more obscure organisms were produced by the fermentation of not-living, and especially of putrefying dead matter, by what was then termed *generatio æquivoca* or *spontanea*, and is now called *abiogenesis*. Redi showed that the general belief was erroneous in a multitude of instances; Spallanzani added largely to the list; while the investigations of the scientific helminthologists of the present century have eliminated a further category of cases in which it was possible to doubt the applicability of the rule "*omne vivum e vivo*" to the more complex organisms which constitute the present fauna and flora of the earth. Even the most extravagant supporters of abiogenesis at the present day do not pretend that organisms of higher rank than the lowest *Fungi* and *Protozoa* are produced otherwise than by generation from pre-existing organisms. But it is pretended that *Bacteria*, *Torulæ*, certain *Fungi*, and "Monads" are developed under conditions which render it impossible that these organisms should have proceeded directly from living matter.

The experimental evidence adduced in favour of this proposition is always of one kind, and the reasoning on which the conclusion that abiogenesis occurs is based may be stated in the following form :—

All living matter is killed by being heated to n degrees.

The contents of the closed vessel A have been heated to n degrees.

Therefore, all living matter which may have existed therein has been killed.

But living *Bacteria*, &c., have appeared in these contents subsequently to their being heated.

Therefore, they have been formed abiogenetically.

No objection can be taken to the logical form of this reasoning, but it is obvious that its applicability to any particular case depends entirely upon the validity, in that case, of the first and second propositions.

Suppose a fluid to be full of *Bacteria* in active motion, what evidence have we that they are killed when that fluid is heated to n degrees? There is but one kind of conclusive evidence, namely, that from that time forth no living *Bacteria* make their appearance in the liquid, supposing it to be properly protected from the intrusion of fresh *Bacteria*. The only other evidence, that, for example, which may be furnished by the cessation of the motion of the *Bacteria*, and such slight changes as our microscopes permit us to observe in their optical characters, is simply presumptive evidence of death, and no more conclusive than the stillness and paleness of a man in a swoon are proof that he is dead. And the caution is the more necessary in the case of *Bacteria*, since many of them naturally pass a considerable part of their existence in a condition in which they show no marks of life whatever save growth and multiplication.

If indeed it could be proved that, in cases which are not open to doubt, living matter is always and invariably killed at precisely the same temperature, there might be some ground for the assumption, that, in those which are obscure, death must take place under the same circumstances. But what are the facts? It has been pointed out at the commencement of this article, that the range of high temperatures between the lowest, at which some living things are certainly killed, and the highest, at which others certainly live, is rather more than 100° Fahr., that is to say, between 104° Fahr. and 208° Fahr. It makes no sort of difference to the argument how living beings have come to be able to bear such a temperature as the last mentioned; the fact that they do so is sufficient to prove that, under certain conditions, such a temperature is not sufficient to destroy life.

Thus it appears that there is no ground for the assumption that all living matter is killed at some given temperature between 104° and 208° Fahr.

But, further, there is very strong reason for believing that the influence of temperature on life is greatly modified, first, by the nature of the medium in which organisms are placed, and, secondly, by the length of time during which any given temperature is kept up.

On this point recent experiments made by Dr Roberts of Manchester are of great importance. He found, for example, as every other careful experimenter has done, that ordinary infusion of hay boiled for a few minutes was sterilized, that is to say, no development of *Bacteria* took place in it, however long it might be kept; while if the infusion was rendered alkaline with ammonia or liquor potassæ, it was not sterilized except after an exposure to the heat of boiling water for more than an hour. Sometimes it became productive after two hours, and once after three hours of such exposure. Is it to be imagined that, in the case of the alkalized hay infusion, the heat applied really killed the *Bacteria* which existed in the infusion, and that *Bacteria* of identically the same kind were generated afresh out of the dead matter? or is it more probable that the powers of resistance of the *Bacteria* to heat were simply increased by the alkalinity of the infusion? The statement of the questions surely render it unnecessary to answer them.

Dr Roberts further proves that there are two factors in the induction of sterilization, the degree of heat on the one hand, and the duration of its application on the other. A longer exposure to a lower temperature was equivalent to a shorter exposure to a higher temperature. "For example, speaking roughly, an exposure of an hour and a half to a heat of 212° Fahr. appeared to be equivalent to an exposure for fifteen minutes to a heat of 228° Fahr."[1]

It is hard to conceive what explanation can be offered of this fact, except that, under the conditions of the experiment, the organisms were either all affected by the first incidence of the heat in such a way as only to arrest some of their vital functions, and to leave a potentiality of life in them, such as exists in some kinds of dried living matter; or that they individually differed very much in their powers of resistance, and that some were able to withstand heat much longer than others.

Under these circumstances it will be evident, that no experimental evidence that a liquid may be heated to n degrees, and yet subsequently give rise to living organisms, is of the smallest value as proof that abiogenesis has taken place, and for two reasons:—Firstly, there is no proof that organisms of the kind in question are dead, except their permanent incapacity to grow and reproduce their kind; and secondly, since we know that conditions may largely modify the power of resistance of such organisms to heat, it is far more probable that such conditions existed in the experiment in question, than that the organisms were generated afresh out of dead matter.

Not only is the kind of evidence adduced in favour of abiogenesis logically insufficient to furnish proof of its occurrence, but it may be stated as a well-based induction, that the more careful the investigator, and the more complete his mastery over the endless practical difficulties which surround experimentation on this subject, the more certain are his experiments to give a negative result; while positive results are no less sure to crown the efforts of the clumsy and the careless.

It is argued that a belief in abiogenesis is a necessary corollary from the doctrine of Evolution. This may be true of the occurrence of abiogenesis at some time; but if the present day, or any recorded epoch of geological time, be in question, the exact contrary holds good. If all living beings have been evolved from pre-existing forms of life, it is enough that a single particle of living protoplasm should once have appeared on the globe, as the result of no matter what agency. In the eyes of a consistent evolutionist any further independent formation of protoplasm would be sheer waste.

The production of living matter since the time of its first appearance, only by way of biogenesis, implies that the specific forms of the lower kinds of life have undergone but little change in the course of geological time, and this is said to be inconsistent with the doctrine of evolution. But, in the first place, the fact is not inconsistent with the doctrine of evolution properly understood, that doctrine being perfectly consistent with either the progression, the retrogression, or the stationary condition of any particular species for indefinite periods of time; and secondly, if it were, it would be so much the worse for the doctrine of evolution, inasmuch as it is unquestionably true, that certain, even highly organized, forms of life have persisted without any sensible change for very long periods. The *Terebratula psittacea* of the present day, for example, is not distinguishable from that of the Cretaceous epoch, while the highly organised Teleostean fish, *Beryx*, of the Chalk differed only in minute specific characters from that which now lives. Is it seriously suggested that the existing *Terebratulæ* and *Beryces* are not the lineal descendants of their Cretaceous ancestors, but that their modern representatives have been independently developed from primordial germs in the interval? But if this is too fantastic a suggestion for grave consideration, why are we to believe that the *Globigerinæ* of the present day are not lineally descended from the Cretaceous forms? And if their unchanged generations have succeeded one another for all the enormous time represented by the deposition of the Chalk and that of the Tertiary and Quaternary deposits, what difficulty is there in supposing that they may not have persisted unchanged for a greatly longer period?

The fact is, that at the present moment there is not a shadow of trustworthy direct evidence that abiogenesis does take place, or has taken place, within the period during which the existence of life on the globe is recorded. But it need hardly be pointed out, that the fact does not in the slightest degree interfere with any conclusion that may be arrived at deductively from other considerations that, at some time or other, abiogenesis must have taken place.

If the hypothesis of evolution is true, living matter must have arisen from not-living matter; for by the hypothesis, the condition of the globe was at one time such that living matter could not have existed in it,[2] life being entirely incompatible with the gaseous state. But living matter once originated, there is no necessity for another origination, since the hypothesis postulates the unlimited, though perhaps not indefinite, modifiability of such matter.

Of the causes which have led to the origination of living matter, then, it may be said that we know absolutely nothing. But postulating the existence of living matter endowed with that power of hereditary transmission, and with that tendency to vary which is found in all such matter, Mr Darwin has shown good reasons for believing that the interaction between living matter and surrounding conditions, which results in the survival of the fittest, is sufficient to account for the gradual evolution of plants and animals from their simplest to their most complicated forms, and for the known phenomena of Morphology, Physiology, and Distribution.

[1] *Proceedings of the Royal Society*, No. 152, p. 290.

[2] It makes no difference if we adopt Sir W. Thomson's hypothesis, and suppose that the germs of living things have been transported to our globe from some other, seeing that there is as much reason for supposing that all stellar and planetary components of the universe are or have been gaseous, as that the earth has passed through this stage.